

ME 210

(9)

Sonntag, Borgnakke and van Wylen

6.44

Liquid water at 180°C, 2000 kPa is throttled into a flash evaporator chamber having a pressure of 500 kPa. Neglect any change in the kinetic energy. What is the fraction of liquid and vapor in the chamber?

Solution:

$$\text{Energy Eq. 6.13: } h_1 + \frac{1}{2} V_1^2 + gZ_1 = h_2 + \frac{1}{2} V_2^2 + gZ_2$$

$$\text{Process: } Z_1 = Z_2 \quad \text{and} \quad V_2 = V_1$$

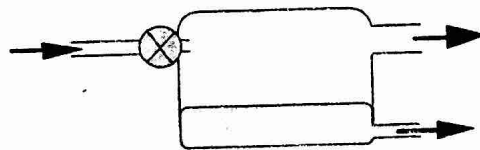
$$\Rightarrow h_2 = h_1 = 763.71 \text{ kJ/kg from Table B.1.4}$$

$$\text{State 2: } P_2 \text{ \& } h_2 \Rightarrow 2\text{-phase}$$

$$h_2 = h_f + x_2 h_{fg}$$

$$x_2 = (h_2 - h_f) / h_{fg} = \frac{763.71 - 640.21}{2108.47} = 0.0586$$

Fraction of	Vapor: $x_2 = 0.0586$	(5.86 %)
	Liquid: $1 - x_2 = 0.941$	(94.1 %)



Two-phase out of the valve. The liquid drops to the bottom.

14/5/2015

33

Turbines, Expanders

6.48

A steam turbine has an inlet of 2 kg/s water at 1000 kPa, 350°C and velocity of 15 m/s. The exit is at 100 kPa, $x = 1$ and very low velocity. Find the specific work and the power produced.

Solution:

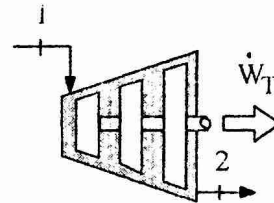
$$\text{Energy Eq. 6.13: } h_1 + \frac{1}{2} V_1^2 + gZ_1 = h_2 + \frac{1}{2} V_2^2 + gZ_2 + w_T$$

$$\text{Process: } Z_1 = Z_2 \quad \text{and} \quad V_2 = 0$$

$$\text{Table B.1.3: } h_1 = 3157.65 \text{ kJ/kg}, \quad h_2 = 2675.46 \text{ kJ/kg}$$

$$w_T = h_1 + \frac{1}{2} V_1^2 - h_2 = 3157.65 + 15^2 / 2000 - 2675.46 = 482.3 \text{ kJ/kg}$$

$$\dot{W}_T = \dot{m} \times w_T = 2 \times 482.3 = 964.6 \text{ kW}$$



6.57

A compressor brings R-134a from 150 kPa, -10°C to 1200 kPa, 50°C . It is water cooled with a heat loss estimated as 40 kW and the shaft work input is measured to be 150 kW. How much is the mass flow rate through the compressor?

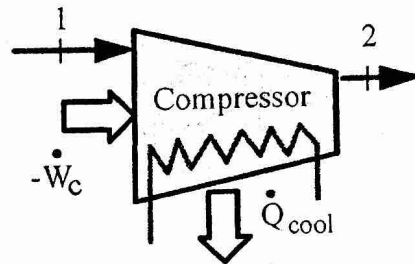
Solution:

C.V Compressor. Steady flow.

Neglect kinetic and potential energies.

$$\text{Energy : } \dot{m} h_i + \dot{Q} = \dot{m} h_e + \dot{W}$$

$$\dot{m} = (\dot{Q} - \dot{W}) / (h_e - h_i)$$



Look in table B.5.2

$$h_i = 393.84 \text{ kJ/kg}, \quad h_e = 426.84 \text{ kJ/kg}$$

$$\dot{m} = \frac{-40 - (-150)}{426.84 - 393.84} = 3.333 \text{ kg/s}$$

7.58

Calculate the amount of work input a refrigerator needs to make ice cubes out of a tray of 0.25 kg liquid water at 10°C. Assume the refrigerator works in a Carnot cycle between -8°C and 35°C with a motor-compressor of 750 W. How much time does it take if this is the only cooling load?

Solution:

C.V. Water in tray. We neglect tray mass.

$$\text{Energy Eq.: } m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$$

$$\text{Process : } P = \text{constant} + P_0$$

$${}_1W_2 = \int P \, dV = P_0 m(v_2 - v_1)$$

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = m(h_2 - h_1)$$

$$\text{Tbl. B.1.1 : } h_1 = 41.99 \text{ kJ/kg, Tbl. B.1.5 : } h_2 = -333.6 \text{ kJ/kg}$$

$${}_1Q_2 = 0.25(-333.4 - 41.99) = -93.848 \text{ kJ}$$

Consider now refrigerator

$$\beta = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L} = \frac{273 - 8}{35 - (-8)} = 6.16$$

$$W = \frac{Q_L}{\beta} = -\frac{{}_1Q_2}{\beta} = \frac{93.848}{6.16} = 15.24 \text{ kJ}$$

For the motor to transfer that amount of energy the time is found as

$$W = \int \dot{W} \, dt = \dot{W} \Delta t$$

$$\Delta t = \frac{W}{\dot{W}} = \frac{15.24 \times 1000}{750} = 20.3 \text{ s}$$

Comment: We neglected a baseload of the refrigerator so not all the 750 W are available to make ice, also our coefficient of performance is very optimistic and finally the heat transfer is a transient process. All this means that it will take much more time to make ice-cubes.

6.59

An air compressor takes in air at 100 kPa, 17°C and delivers it at 1 MPa, 600 K to a constant-pressure cooler, which it exits at 300 K. Find the specific compressor work and the specific heat transfer in the cooler.

Solution

C.V. air compressor $q = 0$

Continuity Eq.: $\dot{m}_2 = \dot{m}_1$

Energy Eq.6.13: $h_1 + w_c = h_2$

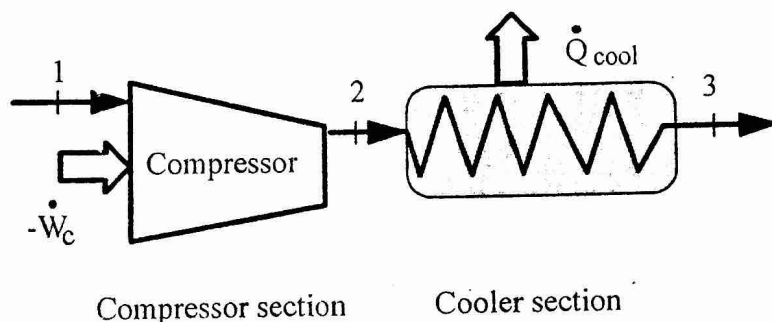


Table A.7:

$$w_{c \text{ in}} = h_2 - h_1 = 607.02 - 290.17 = 316.85 \text{ kJ/kg}$$

C.V. cooler $w = 0$

Continuity Eq.: $\dot{m}_3 = \dot{m}_1$

Energy Eq.6.13: $h_2 = q_{out} + h_3$

$$q_{out} = h_2 - h_3 = 607.02 - 300.19 = 306.83 \text{ kJ/kg}$$

6.66

Saturated liquid nitrogen at 500 kPa enters a boiler at a rate of 0.005 kg/s and exits as saturated vapor. It then flows into a super heater also at 500 kPa where it exits at 500 kPa, 275 K. Find the rate of heat transfer in the boiler and the super heater.

Solution:

C.V.: boiler steady single inlet and exit flow, neglect KE, PE energies in flow

Continuity Eq.: $\dot{m}_1 = \dot{m}_2 = \dot{m}_3$

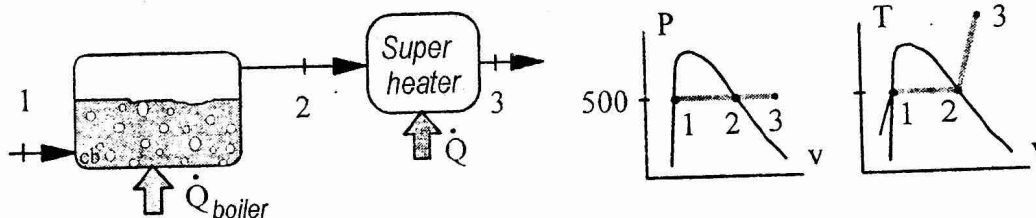


Table B.6.1: $h_1 = -87.095$ kJ/kg, $h_2 = 86.15$ kJ/kg,

Table B.6.2: $h_3 = 284.06$ kJ/kg

Energy Eq.6.13: $q_{boiler} = h_2 - h_1 = 86.15 - (-87.095) = 173.25$ kJ/kg

$$\dot{Q}_{boiler} = \dot{m}_1 q_{boiler} = 0.005 \times 173.25 = \mathbf{0.866 \text{ kW}}$$

C.V. Superheater (same approximations as for boiler)

Energy Eq.6.13: $q_{sup \text{ heater}} = h_3 - h_2 = 284.06 - 86.15 = 197.9$ kJ/kg

$$\dot{Q}_{sup \text{ heater}} = \dot{m}_2 q_{sup \text{ heater}} = 0.005 \times 197.9 = \mathbf{0.99 \text{ kW}}$$

Heat Exchangers

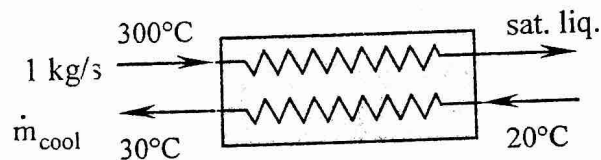
6.84

A condenser (heat exchanger) brings 1 kg/s water flow at 10 kPa from 300°C to saturated liquid at 10 kPa, as shown in Fig. P6.84. The cooling is done by lake water at 20°C that returns to the lake at 30°C. For an insulated condenser, find the flow rate of cooling water.

Solution:

C.V. Heat exchanger

$$\text{Energy Eq. 6.10: } \dot{m}_{\text{cool}} h_{20} + \dot{m}_{\text{H}_2\text{O}} h_{300} = \dot{m}_{\text{cool}} h_{30} + \dot{m}_{\text{H}_2\text{O}} h_{f, 10 \text{ kPa}}$$



$$\text{Table B.1.1: } h_{20} = 83.96 \text{ kJ/kg}, \quad h_{30} = 125.79 \text{ kJ/kg}$$

$$\text{Table B.1.3: } h_{300, 10 \text{ kPa}} = 3076.5 \text{ kJ/kg}, \quad \text{B.1.2: } h_{f, 10 \text{ kPa}} = 191.83 \text{ kJ/kg}$$

$$\dot{m}_{\text{cool}} = \dot{m}_{\text{H}_2\text{O}} \frac{h_{300} - h_{f, 10 \text{ kPa}}}{h_{30} - h_{20}} = 1 \times \frac{3076.5 - 191.83}{125.79 - 83.96} = 69 \text{ kg/s}$$

7.64

A heat pump is driven by the work output of a heat engine as shown in figure P7.64. If we assume ideal devices find the ratio of the total power $\dot{Q}_{L1} + \dot{Q}_{H2}$ that heats the house to the power from the hot energy source $\dot{Q}_{H1}$ in terms of the temperatures.

$$\beta_{HP} = \dot{Q}_{H2} / \dot{W} = \dot{Q}_{H2} / (\dot{Q}_{H2} - \dot{Q}_{L2}) = \frac{T_{room}}{T_{room} - T_{amb}}$$

$$\dot{W} = \eta_{HE} \cdot \dot{Q}_{H1} = \left(1 - \frac{T_{room}}{T_H}\right) \dot{Q}_{H1}$$

$$\dot{W} = \dot{Q}_{H2} / \beta_{HP} = \frac{T_{room}}{T_{room} - T_{amb}} \dot{Q}_{H2}$$

$$\dot{Q}_{L1} = \dot{Q}_{H1} - \dot{W} = \left[1 - 1 + \frac{T_{room}}{T_H}\right] \dot{Q}_{H1}$$

$$\begin{aligned} \frac{\dot{Q}_{H2} + \dot{Q}_{L1}}{\dot{Q}_{H1}} &= 1 - 1 + \frac{T_{room}}{T_H} + \frac{1 - \frac{T_{room}}{T_H}}{\frac{T_{room} - T_{amb}}{T_{room}}} \\ &= \frac{T_{room}}{T_H} + \frac{T_{room} - T_{room}^2/T_H}{T_{room} - T_{amb}} \\ &= T_{room} \left[\frac{1}{T_H} + \frac{1 - \frac{T_{room}}{T_H}}{T_{room} - T_{amb}} \right] \\ &= \frac{T_{room}}{T_H} \left[1 + \frac{T_H - T_{room}}{T_{room} - T_{amb}} \right] \\ &= \frac{T_{room}}{T_H} \left[\frac{T_H - T_{amb}}{T_{room} - T_{amb}} \right] \end{aligned}$$

7.65

It is proposed to build a 1000-MW electric power plant with steam as the working fluid. The condensers are to be cooled with river water (see Fig. P7.65). The maximum steam temperature is 550°C, and the pressure in the condensers will be 10 kPa. Estimate the temperature rise of the river downstream from the power plant.

Solution:

$$\dot{W}_{\text{NET}} = 10^6 \text{ kW}, \quad T_H = 550^\circ\text{C} = 823.3 \text{ K}$$

$$P_{\text{COND}} = 10 \text{ kPa} \rightarrow T_L = T_G (P = 10 \text{ kPa}) = 45.8^\circ\text{C} = 319 \text{ K}$$

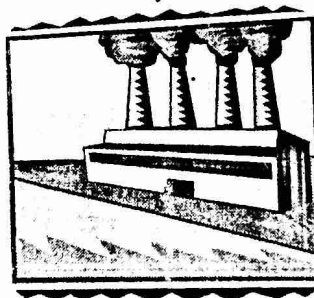
$$\eta_{\text{TH CARNOT}} = \frac{T_H - T_L}{T_H} = \frac{823.2 - 319}{823.2} = 0.6125$$

$$\Rightarrow \dot{Q}_{L \text{ MIN}} = 10^6 \left(\frac{1 - 0.6125}{0.6125} \right) = 0.6327 \times 10^6 \text{ kW}$$

$$\text{But } \dot{m}_{\text{H}_2\text{O}} = \frac{60 \times 8 \times 10/60}{0.001} = 80\,000 \text{ kg/s} \text{ having an energy flow of}$$

$$\dot{Q}_{L \text{ MIN}} = \dot{m}_{\text{H}_2\text{O}} \Delta h = \dot{m}_{\text{H}_2\text{O}} C_{P \text{ LIQ H}_2\text{O}} \Delta T_{\text{H}_2\text{O MIN}}$$

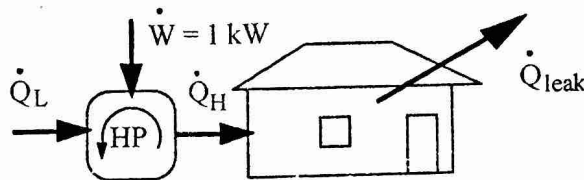
$$\Rightarrow \Delta T_{\text{H}_2\text{O MIN}} = \frac{\dot{Q}_{L \text{ MIN}}}{\dot{m}_{\text{H}_2\text{O}} C_{P \text{ LIQ H}_2\text{O}}} = \frac{0.6327 \times 10^6}{80000 \times 4.184} = 1.9^\circ\text{C}$$



7.74

A heat pump has a coefficient of performance that is 50% of the theoretical maximum. It maintains a house at 20°C , which leaks energy of 0.6 kW per degree temperature difference to the ambient. For a maximum of 1.0 kW power input find the minimum outside temperature for which the heat pump is a sufficient heat source.

Solution:



C.V. House. For constant 20°C the heat pump must provide $\dot{Q}_{\text{leak}} = 0.6 \Delta T$

$$\dot{Q}_H = \dot{Q}_{\text{leak}} = 0.6 (T_H - T_L) = \beta' \dot{W}$$

C.V. Heat pump. Definition of the coefficient of performance and the fact that the maximum is for a Carnot heat pump.

$$\beta' = \dot{Q}_H / \dot{W} = \dot{Q}_H / (\dot{Q}_H - \dot{Q}_L) = 0.5 \beta'_{\text{Carnot}} = 0.5 \times T_H / (T_H - T_L)$$

Substitute into the first equation to get

$$0.6 (T_H - T_L) = [0.5 \times T_H / (T_H - T_L)] 1 \Rightarrow$$

$$(T_H - T_L)^2 = (0.5 / 0.6) T_H \times 1 = 0.5 / 0.6 \times 293.15 = 244.29$$

$$T_H - T_L = 15.63 \Rightarrow T_L = 20 - 15.63 = 4.4^\circ\text{C}$$

8.70

A piston/cylinder contains 1 kg water at 150 kPa, 20°C. The piston is loaded so pressure is linear in volume. Heat is added from a 600°C source until the water is at 1 MPa, 500°C. Find the heat transfer and the total change in entropy.

Solution

CV: H₂O out to the source, both ${}_1Q_2$ and ${}_1W_2$

Energy Eq. 5.11: $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Entropy Eq. 8.14: $m(s_2 - s_1) = {}_1Q_2 / T_{\text{SOURCE}} + {}_1S_2 \text{ gen}$

Process: $P = A + BV \Rightarrow {}_1W_2 = \int P dV = \frac{1}{2} (P_1 + P_2) (V_2 - V_1)$

State 1: B.1.1 Compressed liquid use saturated liquid at same T:

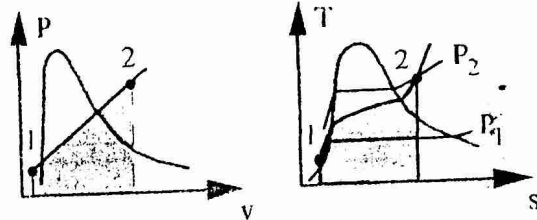
$$v_1 = 0.001002 \text{ m}^3/\text{kg}; \quad u_1 = 83.94 \text{ kJ/kg}; \quad s_1 = 0.2966 \text{ kJ/kg K}$$

State 2: Table B.1.3 sup. vap.

$$v_2 = 0.35411 \text{ m}^3/\text{kg}$$

$$u_2 = 3124.3 \text{ kJ/kg};$$

$$s_2 = 7.7621 \text{ kJ/kg K}$$



$${}_1W_2 = \frac{1}{2} (1000 + 150) (0.35411 - 0.001002) = 203 \text{ kJ}$$

$${}_1Q_2 = 1(3124.3 - 83.94) + 203 = 3243.4 \text{ kJ}$$

$$m(s_2 - s_1) = 1(7.7621 - 0.2968) = 7.4655 \text{ kJ/K}$$

$${}_1Q_2 / T_{\text{source}} = 3.7146 \text{ kJ/K} \quad (\text{for source } Q = -{}_1Q_2 \text{ recall Eq. 8.18})$$

$${}_1S_2 \text{ gen} = m(s_2 - s_1) - {}_1Q_2 / T_{\text{source}} = \Delta S_{\text{total}}$$

$$= \Delta S_{\text{H}_2\text{O}} + \Delta S_{\text{source}} = 7.4655 - 3.7146 = 3.751 \text{ kJ/K}$$

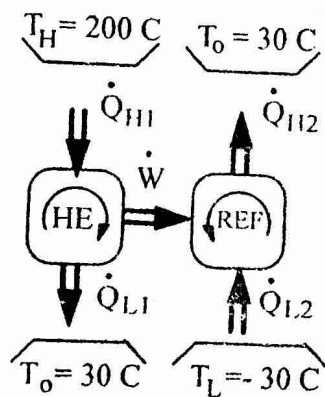
Remark: This is an external irreversible process (ΔT to the source)

7.84

We wish to produce refrigeration at -30°C . A reservoir, shown in Fig. P7.84, is available at 200°C and the ambient temperature is 30°C . Thus, work can be done by a cyclic heat engine operating between the 200°C reservoir and the ambient. This work is used to drive the refrigerator. Determine the ratio of the heat transferred from the 200°C reservoir to the heat transferred from the -30°C reservoir, assuming all processes are reversible.

Solution:

Equate the work from the heat engine to the refrigerator.



$$W = Q_{H1} \left(\frac{T_H - T_o}{T_H} \right)$$

also

$$W = Q_{L2} \left(\frac{T_o - T_L}{T_L} \right)$$

$$\frac{Q_{H1}}{Q_{L2}} = \left(\frac{T_o - T_L}{T_L} \right) \left(\frac{T_H}{T_H - T_o} \right) = \left(\frac{60}{243.2} \right) \left(\frac{473.2}{170} \right) = 0.687$$

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7.17

A remote location without electricity operates a refrigerator with a bottle of propane feeding a burner to create hot gases. Sketch the setup in terms of cyclic devices and give a relation for the ratio of $\dot{Q}_L$ in the refrigerator to $\dot{Q}_{\text{fuel}}$ in the burner in terms of the various reservoir temperatures.

The work of the heat engine assuming Carnot efficiency is

$$\dot{W} = \eta_{\text{HE}} \dot{Q}_{\text{fuel}} = \left(1 - \frac{T_{\text{amb}}}{T_{\text{fuel}}}\right) \dot{Q}_{\text{fuel}}$$

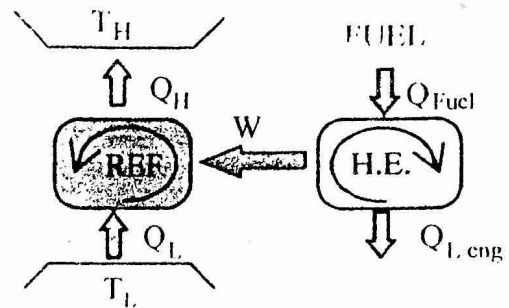
The work required by the refrigerator assuming reversible COP is

$$\dot{W} = \dot{Q}_L / \beta_{\text{ref}} = \dot{Q}_L \frac{T_{\text{amb}} - T_L}{T_L}$$

Set the two work terms equal and solve for $\dot{Q}_L$.

$$\dot{Q}_L = \frac{T_L}{T_{\text{amb}} - T_L} \dot{W} = \frac{T_L}{T_{\text{amb}} - T_L} \left(1 - \frac{T_{\text{amb}}}{T_{\text{fuel}}}\right) \dot{Q}_{\text{fuel}}$$

Remark: This result is optimistic since we used Carnot cycle efficiency and coefficient of performance. Secondly the heat transfer requires a ΔT so the heat engine efficiency is lower and the COP is lower.



ملاحظات هامة: اقرأ التعليمات التالية بعناية

- 1- يسمح باستخدام الجداول المقررة فقط.
- 2- لا يسمح باستعادة الجداول أثناء الامتحان.
- 3- تحظر اليوناف المحمولة والآلات الحاسبة المتطورة.
- 4- تأكد من كتابة الاسم، ورقم القيد، والمجموعة، والقسم.
- 5- ثابت الغاز العام $\bar{R} = 8.314 \text{ kJ/kmol} \cdot \text{K}$.
- 6- أجب عن جميع الأسئلة في الفراغ المخصص لكل سؤال.

السؤال الأول:

(13 درج)

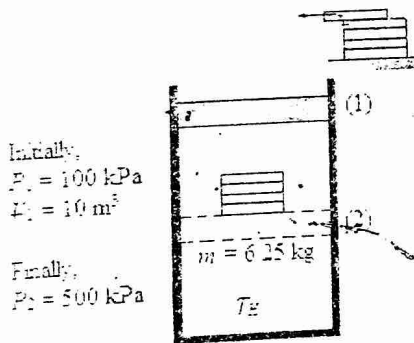
- 1- صف الكميات التالية إلى: دالة نقطة (point function) أو دالة مسار (path function) أو ثابت (constant) (3 درجات)

Total Internal Energy	
Work	
Heat	

Temperature	
Pv/T for an ideal gas	
Specific Heat	

- 2- تمنح (درجة واحدة فقط) في حال عدم نسيانك كتابة اسمك، ورقم قيدك، والمجموعة، والقسم، ورقم التسلسل في المكان المخصص.
- 3- في الشكل المرفق، آلة حرارية تشتغل طبقاً لدورة كارنو بين خزانين حراريين ثابتي درجة الحرارة T_H و $T_L = 27^\circ\text{C}$. الخزان الحراري مرتفع درجة الحرارة عبارة عن منظومة مغلقة بها 6.25 kg من غاز مثالي عند $P_1 = 100 \text{ kPa}$ و $V_1 = 10 \text{ m}^3$ في الحث الابتدائية (1). تضاف الانتقال واحدة تلو الأخرى على المكبس بحيث يزداد الضغط تدريجياً ويبطئ إلى أن يصل ضغط المنظومة المغلقة إلى $P_2 = 500 \text{ kPa}$ في الحالة النهائية (2). خلال هذه العملية يتم السماح بانتقال كمية الحرارة Q_{in} إلى الآلة الحرارية بحيث تبقى درجة حرارة الغاز ثابتة داخل المنظومة المغلقة. بين العملية التي يخضع لها الغاز على مخططي $P - V$ و $T - S$. إذا علمت أن الكتلة المولية للغاز ($M = 41.57 \text{ kg/kmol}$)، وأن تأثير طاقتي الحركة والوضع للمنظومة المغلقة مهم، فأحسب:
 - 1- درجة حرارة المنظومة المغلقة T_H بوحدة $^\circ\text{C}$.
 - 2- الشغل المنتج للآلة الحرارية $W_{net,out}$ بوحدة kJ.
 - 3- كمية الحرارة المطرودة Q_L بوحدة kJ.

(9 درجات)

Low-temperature reservoir
at $T_L = 27^\circ\text{C}$

(12 در)

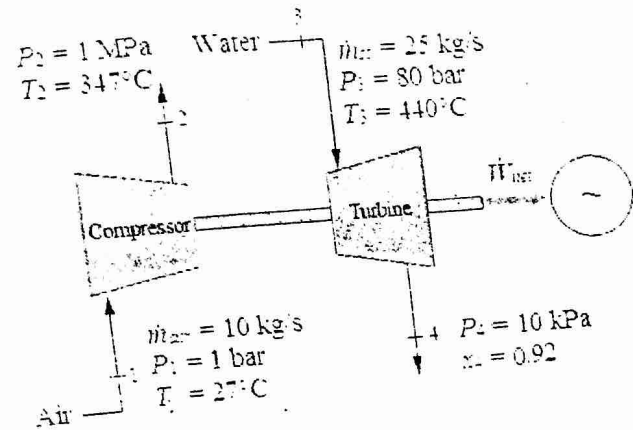
في الشكل المرفق، يستغل جزء من قدرة التربين البخاري المنتجة لتشغيل الضاغط، بينما يستغل الباقي لتزويد مولد (generator). بافتراض الهواء له سلوك الغاز المثالي، وعملية التدفق للتربين والضاغط مستقرة وكاظمة للحرارة، وتأثير طقتي الحركة والوضع مهم، فاحسب:

1- الشغل اللازم لتشغيل الضاغط بـ kJ/kg باستخدام جدول A-22.

2- الشغل المنتج من التربين بـ kJ/kg .

3- صافي القدرة المشغلة للمولد بـ MW.

4- إذا تم تركيب صمام (جهاز خنق) عند مدخل التربين، وآخر عند مدخل الضاغط، فهل يا ترى ستتغير النتيجة المتحصل عليها في كل من الفقرة (1) و (2)؟ ولماذا؟



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فصل الربيع 2013

السؤال الأول: (12/20 نقطة)

الزمن: ساعة

Question #1: (12/20 points)

piston-cylinder device (Free Piston), initially contains 5 kg of water with quality of 25% at 1.5 bar. Heat is added to the system until its temperature becomes 150 °C. Neglecting the change in kinetic and potential energies. Determine:

- The initial temperature and initial volume.
- The work done in the process. Is the work done by or on the system.
- Show the process on the P-V diagram.
- The internal energy of the substance at initial and final state.
- The amount of heat transferred to the system during the process.

منظومة مكبس و أسطوانة (المكبس حر الحركة)، تحتوي في الحالة الابتدائية على 5 كجم من الماء بجودة بخار تساوي 25% وضغط 1.5 بار. أضيفت كمية من الحرارة الى النظام الى أن أصبحت درجة حرارته تساوي 150 درجة مئوية. بإهمال التغير في طاقتي الحركة والوضع، احسب:

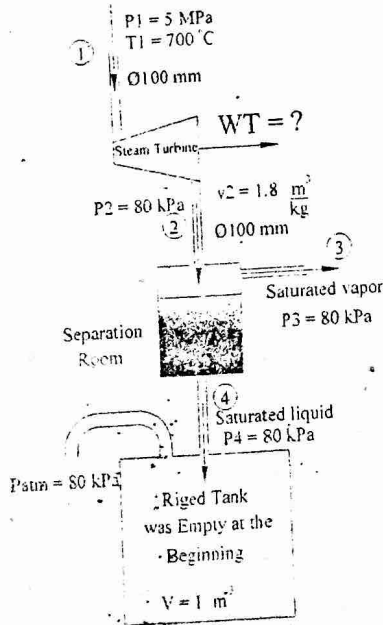
1. درجة الحرارة الابتدائية والحجم الابتدائي.
2. الشغل المبذول خلال العملية. وهل الشغل بُذل على النظام، أم بواسطة النظام.
3. وضع العملية على مخطط P-V.
4. الطاقة الداخلية عند الحالة الابتدائية والنهائية.
5. كمية الحرارة المنتقلة الى النظام خلال العملية.

السؤال الثاني (8/20 نقاط)

Question # 2: (8/20 points)

In the figure shown below, calculate the power produced by the adiabatic steam turbine from the start up until the Rigid tank is fully filled by saturated liquid during 10 min, if the flow through the turbine is SSSF.

في الشكل الموضح ادناه، احسب القدرة الناتجة من التربين البخارية التي تعمل بواسطة الماء من بداية التشغيل حتى يمتلئ الخزان الجاسئ بالكامل بالسائل المشبع والذي يستغرق 10 دقائق إذا كان التدفق خلال التربين مستقر والحالة مستقرة وكان التربين كاظم للحرارة.



تمنياتنا للجميع بالتوفيق.....

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الإجابة النموذجية للاختبار الدوري الثاني لمقرر ME210

Q1

Q1 1)-

$$P1 := 1.5 \cdot \text{bar}$$

$$T1 = T_{\text{sat}} @ P1$$

$$T1 := 111.4^{\circ} \text{C}$$

2)-

$$x1 := 0.25$$

$$m1 := 5 \cdot \text{kg}$$

$$v_{f1} := 0.0010528 \frac{\text{m}^3}{\text{kg}}$$

$$v_{g1} := 1.159 \frac{\text{m}^3}{\text{kg}}$$

$$v1 := v_{f1} + x1 \cdot (v_{g1} - v_{f1})$$

$$v1 = 0.291 \frac{\text{m}^3}{\text{kg}}$$

$$V1 = 1.4527 \text{m}^3$$

$$V1 := m1 \cdot v1$$

$$W12 = P1 \cdot (V2 - V1)$$

at

$$T2 := 160^{\circ} \text{C}$$

$$P_{\text{sat}} := 6.178 \cdot \text{bar}$$

and

$$P2 := P1$$

$$\& \quad m2 := m1$$

state 2 is superheated

$$v2 := 1.317 \frac{\text{m}^3}{\text{kg}}$$

$$V2 := v2 \cdot m2$$

$$V2 = 6.585 \text{m}^3$$

$$W12 := P1 \cdot (V2 - V1)$$

$$W12 = 769.845 \text{J}$$

+ve signe thus the work done by the system

3) -

$$u_{f1} := 466.94 \cdot \frac{\text{kJ}}{\text{kg}}$$

$$u_{g1} := 2519.7 \cdot \frac{\text{kJ}}{\text{kg}}$$

$$u_1 := u_{f1} + x_1 \cdot (u_{g1} - u_{f1})$$

$$u_1 = 980.13 \frac{\text{kJ}}{\text{kg}}$$

$$U_1 := m_1 \cdot u_1$$

$$U_1 = 4900.65 \text{ kJ}$$

u_2 at 1.5 bar and 160 °C

$$u_2 = 2595.2 \cdot \frac{\text{kJ}}{\text{kg}}$$

$$U_2 := m_2 \cdot u_2$$

$$U_2 = 12976 \text{ kJ}$$

4) -

$$Q_{12} = m \cdot (u_2 - u_1) + m \cdot \left(\frac{c_2^2 - c_1^2}{2} \right) + [m \cdot g \cdot (z_2 - z_1)] + W_{12}$$

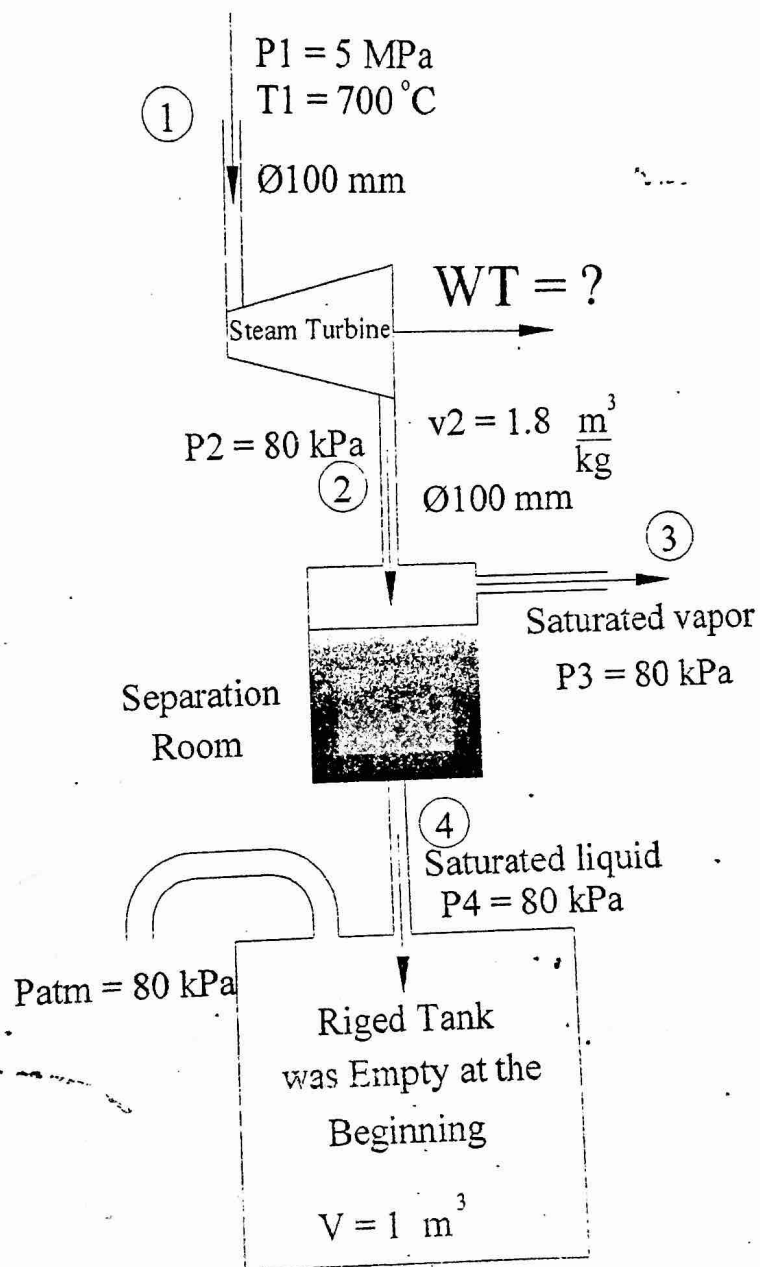
dKE & dPE are very small compare by dU thus it can be negligible

Thus

$$Q_{12} := W_{12} + U_2 - U_1$$

$$Q_{12} = 8845.2 \text{ kJ}$$

Q2



2

$$kJ := 1000 \cdot J$$

$$MPa := 1000000 \cdot Pa$$

$$kPa := 1000 \cdot Pa$$

$$P1 := 5 \cdot MPa$$

$$t := 10 \cdot min$$

$$T1 := 700 \text{ } ^\circ C$$

$$h1 := \frac{3905.9 + 3894.1}{2} \cdot \frac{kJ}{kg}$$

$$v1 := \frac{0.111 + 0.07352}{2} \cdot \frac{m^3}{kg}$$

$$v1 = 0.092 \cdot \frac{m^3}{kg}$$

$$h1 = 3900 \cdot \frac{kJ}{kg}$$

$$v2 := 1.8 \cdot \frac{m^3}{kg}$$

$$P2 := 80 \cdot kPa$$

$$vf2 := 1.0380 \cdot 10^{-3} \cdot \frac{m^3}{kg}$$

$$vg2 := 2.087 \cdot \frac{m^3}{kg}$$

$$vf2 < v2 < vg2$$

Thus the state at point 2 is mixture

$$x2 := \frac{v2 - vf2}{vg2 - vf2}$$

$$x2 = 0.862$$

$$hf2 := 391.66 \cdot \frac{kJ}{kg}$$

$$hfg2 := 2274.1 \cdot \frac{kJ}{kg}$$

$$hg2 := 2665.8 \cdot \frac{kJ}{kg}$$

$$h2 := hf2 + x2 \cdot hfg2$$

$$h2 = 2352.9 \cdot \frac{kJ}{kg}$$

$$Vt := 1 \cdot m^3$$

$$mf := \frac{Vt}{vf2}$$

$$mf = 963.391 \text{ kg}$$

$$mt := \frac{mf}{1 - x2}$$

$$mt = 7002.08 \text{ kg}$$

22

$$md := \frac{m}{t}$$

$$d := 100 \cdot \text{mm}$$

$$A1 := \frac{\pi \cdot d^2}{4}$$

$$c1 := \frac{md \cdot v1}{A1}$$

$$c2 := \frac{md \cdot v2}{A1}$$

$$MW := 10^6 \cdot W$$

$$WT := md \cdot \left[(h1 - h2) + \frac{c1^2}{2000} - \frac{c2^2}{2000} \right]$$

$$md = 11.67 \frac{\text{kg}}{\text{sec}}$$

$$A1 = 7.854 \times 10^{-3} \text{ m}^2$$

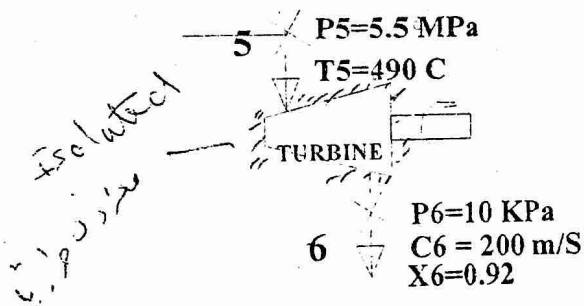
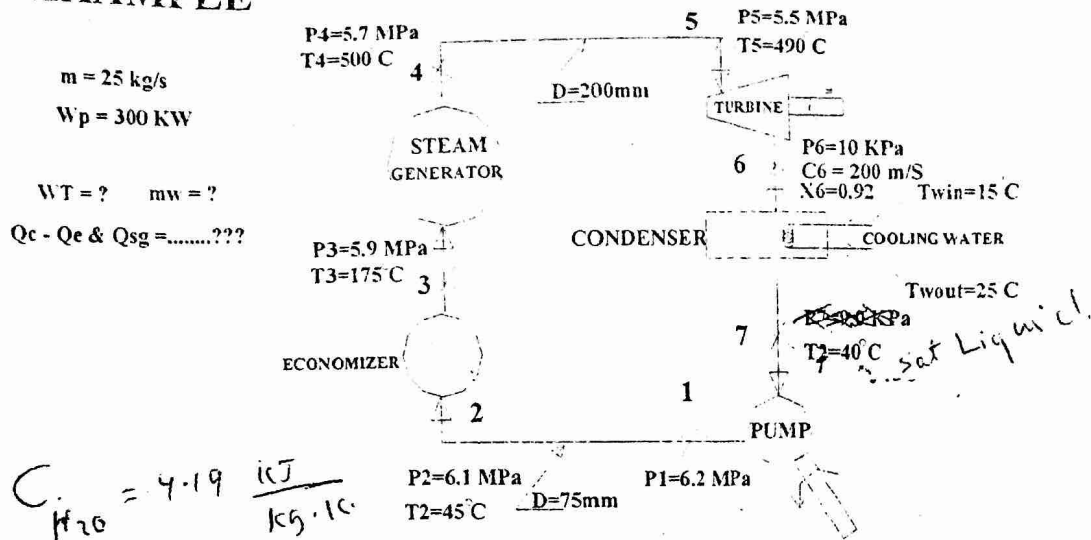
$$c1 = 137.09 \text{ m s}^{-1}$$

$$c2 = 2674.6 \text{ m s}^{-1}$$

$$WT = 18013.53 \text{ kW}$$

$$WT = 18.014 \text{ MW}$$

EXAMPLE



$$m_w := 25 \cdot \frac{\text{kg}}{\text{s}}$$

Applying First Law of thermodynamics:-

$$Q_{56} - W_{56} = m \cdot g \cdot (Z_6 - Z_5) + m \cdot \left(\frac{v_6^2 - v_5^2}{2} \right) + m \cdot (h_6 - h_5)$$

$$Q_{56} = 0 \cdot \text{J} \quad Z_6 - Z_5 = 0 \cdot \text{m} \quad \text{Very small} \quad m = \text{constant}$$

$$W_{56} = m \cdot \left(\frac{v_6^2 - v_5^2}{2} \right) + m \cdot (h_6 - h_5)$$

At turbine inlet (5) and by using steam tables we may find:

$$P := 5.0 \cdot \text{MPa}$$

$$P := 5.5 \cdot \text{MPa}$$

$$P := 6.0 \cdot \text{MPa}$$

T	v	h
450	0.0633	3316.2

v	h
0.05214	3301.8

v	h
0.05214	3301.8

490

v = ... h = ...

500	0.06857	3433.8
-----	---------	--------

0.05665	3422.2
---------	--------

At 5.5 MPa & 450 C

$$v_{450} := \left[\frac{5.5 - 5}{6 - 5} \cdot (0.05214 - 0.0633) + 0.0633 \right] \cdot \frac{\text{m}^3}{\text{kg}}$$

$$v_{450} = 0.05772 \frac{\text{m}^3}{\text{kg}}$$

$$h_{450} := \left[\frac{5.5 - 5}{6 - 5} \cdot (3301.8 - 3316.2) + 3316.2 \right] \cdot \frac{\text{kJ}}{\text{kg}}$$

$$h_{450} = 3309 \frac{\text{kJ}}{\text{kg}}$$

At 5.5 MPa & 500 C

$$v_{500} := \left[\frac{5.5 - 5}{6 - 5} \cdot (0.05665 - 0.06857) + 0.06857 \right] \cdot \frac{\text{m}^3}{\text{kg}}$$

$$v_{500} = 0.06261 \frac{\text{m}^3}{\text{kg}}$$

$$h_{500} := \left[\frac{5.5 - 5}{6 - 5} \cdot (3422.2 - 3433.8) + 3433.8 \right] \cdot \frac{\text{kJ}}{\text{kg}}$$

$$h_{500} = 3428 \frac{\text{kJ}}{\text{kg}}$$

$$P := 5.5 \cdot \text{MPa}$$

$$v_{490} := \left[\frac{490 - 450}{500 - 450} \cdot (0.06261 - 0.05772) + 0.05772 \right] \cdot \frac{\text{m}^3}{\text{kg}}$$

$$v_{490} = 0.06132 \frac{\text{m}^3}{\text{kg}}$$

T	v	h
450	0.05772	3309

490

500	0.06261	3428
-----	---------	------

$$h_{490} := \left[\frac{490 - 450}{500 - 450} \cdot (3428 - 3309) + 3309 \right] \cdot \frac{\text{kJ}}{\text{kg}}$$

$$h_{490} = 3404.2 \frac{\text{kJ}}{\text{kg}}$$

$$v_5 := v_{490} \cdot \frac{\text{m}^3}{\text{kg}}$$

$$h_5 := h_{490} \cdot \frac{\text{kJ}}{\text{kg}}$$

$$m = \rho \cdot v \cdot A$$

At turbine inlet (6) and by using steam tables we may find:

$$v_{f6} := 0.001010 \cdot \frac{\text{m}^3}{\text{kg}}$$

$$v_{g6} := 14.67 \cdot \frac{\text{m}^3}{\text{kg}}$$

$$x := 0.92$$

$$v_{fg6} := v_{g6} - v_{f6}$$

$$v_6 := v_{f6} + x \cdot v_{fg6}$$

$$v_6 = 13.496 \frac{\text{m}^3}{\text{kg}}$$

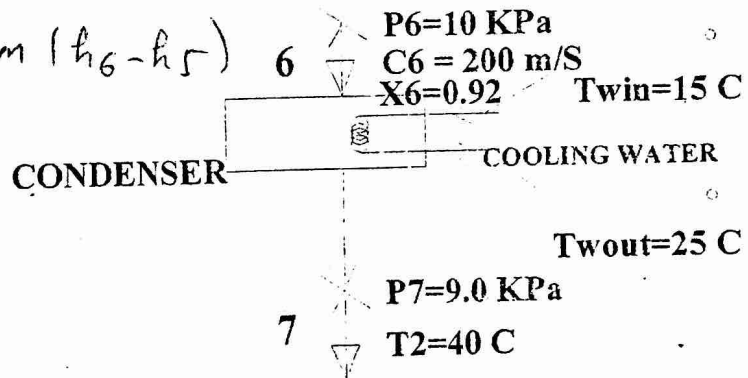
$$h_{f6} := 191.83 \cdot \frac{\text{kJ}}{\text{kg}}$$

$$h_{fg6} := 2392.8 \cdot \frac{\text{kJ}}{\text{kg}}$$

$$h_6 := h_{f6} + x \cdot h_{fg6}$$

$$h_6 = 2393.206 \frac{\text{kJ}}{\text{kg}}$$

$$W_T = m \left(\frac{C_6^2 - C_5^2}{2} \right) + m (h_6 - h_5)$$



$$C_6 = 200 \text{ m/s}$$

$$\dot{m} = \rho V_6 A$$

$$A_5 = A_6 = \frac{\pi d^2}{4}$$

$$\dot{m} = \rho_6 V_6 A_6 = \frac{C_6 A_6}{v_6}$$

$$C_5 = \frac{\dot{m} \cdot v_5}{A_5}$$

با استفاده از، کتاب، و

$$W_T = \dots$$

condenser

$$W_{6-7} = 0$$

$$\Delta PE = 0$$

مقدار، تفاوت، در